TRAVELLING AT HIGH SPEEDS ON THE SURFACE OF THE EARTH AND ABOVE IT.[1]

"The Spirit of the time shall teach me Speed."—*King John.*

THERE are few things so important to man from a material point of view as the power of locomotion; seeing, therefore, that in this respect he is far less well endowed by nature than many, if not most, living creatures, it is no wonder that he has striven from the earliest times to overcome his inferiority by means of mechanical devices. The marvellous results of these unceasing attempts which to-day we enjoy, or, as some people would prefer to say, "take advantage of," are accepted by most of us as a mere matter of course, and we are further apt to assume that the progress which has been so marked during the last century, and particularly in recent years, will continue indefinitely. Now, quite apart from mere locomotion, the question of speed is one of great scientific interest, and, more than this, it is the real test of the power of locomotion. This is not a mere accident, but has its root in something far deeper. The desire for speed is a quality inherent in man, and is doubtless a primordial instinct, the reason for which we see in all other animals, being derived from prehistoric ages, when speed was a necessity of life to enable the weak to escape from the strong and to enable the strong to prey upon the weak, and man depended, just as the animals in prehistoric times, for his life on his fleetness and speed of motion.

From what few and somewhat uncertain records we have of the achievements of man in running in the ancient sports, it does not seem there is very much difference between his powers then and in modern times. As to modern times, we find that for the short distance of 100 yards, and for the longer distance of a mile, the records of twenty-five years ago still stand, notwithstanding the strenuous efforts made to improve upon them on many scores of occasions each subsequent year. Thus we have for the former the record of E. Donnovan in 1886, 21·3 miles an hour, and in the same year the record of W. G. George for the mile, 14·2 miles an hour, which have never been beaten; while for one distance, that of 200 yards, the record of Sewards in 1847, or sixty-four years ago, still stands. In fact, a study of all the records of twenty-five distances shows that several of them remain unbroken after comparatively long periods, viz. from a quarter to half a century.

Thus, so far as his own unaided powers of locomotion are concerned, man may be considered, for all practical purposes, to have reached long ago the limit of speed possibility. From earliest times, however, he has brought the muscular effort of other animals into his service, and has devoted his intellect towards improving their speed for his own uses. You will see graphically recorded in Fig. 1 the speeds of all the Derby winners from the year 1856, *i.e.* for more than half a century. The average speed, which may be taken as somewhere above 30 miles an hour, has doubtless slightly increased, but it will be seen from the dotted line which has been drawn at the top of the maximum speeds what comparatively little increase has been obtained for an expenditure of the many millions represented directly and indirectly in the training and breeding of these horses, and it may be reasonably assumed that here again the limit has been reached for the fleetest animal, by the aid of which man can increase his speed of locomotion by using muscular power other than his own.

What, then, are the physical reasons for this limitation? It is not due to the chief cause, which we shall see later puts a practical limit to very high speeds in mechanical locomotion, namely, the resistance of the atmosphere. Neither is it due to the effective work done in movement, since with a body moving along a level plain, *i.e.* at a constant distance from the earth's centre, this effective work is nil. To understand the matter we must study the nature of animal locomotion. The surface of the earth is rough, sliding along it being obviously out of the question; nature has made provision for animal movement as follows:—one part of the body first rests on the ground, another part supported by this is advanced, being raised clear of the ground, to rest in turn upon the ground and serve in turn as a support, so that the part behind may be raised and advanced to a fresh position. In man and other animals the feet form the points of support for this process; but the same method of locomotion is employed by creatures without feet, which have to crawl or glide, such as snakes or worms.

This process, whether with animals or reptiles, as you will see, involves in the raising of the body an expenditure of work which is not recovered, and further an expenditure of work in stopping and starting some portion of the body in its movements. My assistant now walks in front of the blackboard holding a piece of chalk level with his head, and you will see the rising and falling motion. I have prepared a wooden model to represent the action of his legs, and you will see that these legs, being equal to his in length, produce almost exactly the same curve underneath, so that you have a complete explanation of this movement, viz. the rotation of the hip about the ankle as a pivot. There is a third case of loss, namely, the energy involved in swinging the legs. About thirty years ago the distinguished French professor, Marey, actually investigated the loss involved from each of these three causes, and I have on the wall a diagram in which you will see all three given graphically. The number of steps per minute, you will notice, increases until a pace is reached when it becomes painful to walk faster, and you will also notice from the diagram that at about ninety steps per minute the gait changes to a run, that is to say, a springing action takes place, the hind foot leaving the ground before the front is put down upon it.

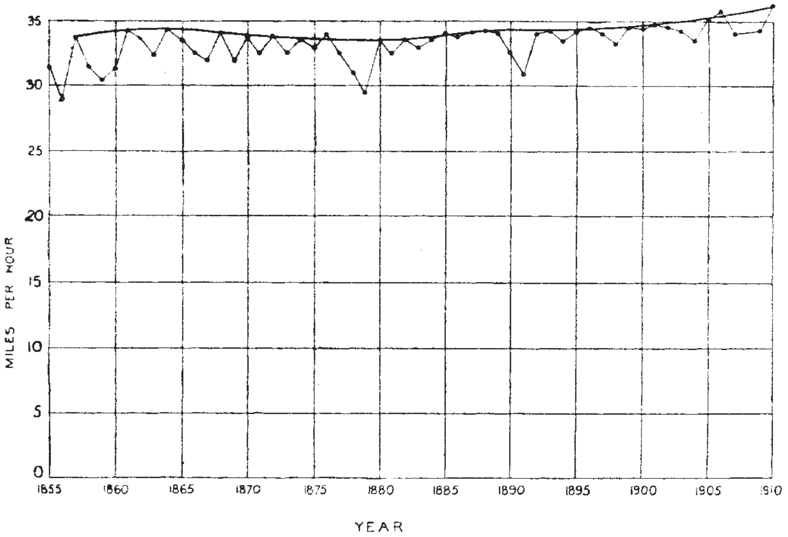

FIG. 1.—Derby Winners for 55 years.

I have another diagram showing how the length of stride at first increases with the pace, and afterwards begins to fall off before the walking breaks into a run. The reason why a man or an animal changes his pace at this point is obvious, and it is because a faster speed is possible with a less effort. As the speed of running is increased the total effort becomes greater, but the three elements shown on the diagram are differently divided; the rise and fall element is less, but the work done in swinging the legs is more, while the chief element, in the muscular effort expended, is the loss of energy involved in stopping and starting as each spring reaches a maximum. Time does not permit me to pursue this interesting subject further except to point out that exactly similar causes operate in the natural locomotion of other animals which move on legs.

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[1] Discourse delivered at the Royal Institution on Friday, March 31, by Prof. H. S. Hele-Shaw, F.R.S.

We therefore now know that the limit of speed is controlled by two factors:—

(1) Physical endurance, owing to the expenditure of work occurring at an increasing rate as the speed is increased.

(2) The physical impossibility of giving a reciprocating movement to the legs quicker than a certain limited period of time.

I have prepared a chart, Fig. 2, which shows the maximum recorded velocities of man's progression in walking and running. The speeds are set up as vertical ordinates, and the abscissæ represent the distances over which the respective speeds were maintained. It will be seen that the maximum speed of walking is about 9 miles an hour for a short distance, but when the long distance of 100 miles is covered, the quickest rate recorded falls to 5½ miles an hour. For running, the quickest speed which I have mentioned, viz. 21½ miles an hour for 100 yards, falls to 7½ miles an hour as the average speed for a distance of 100 miles.

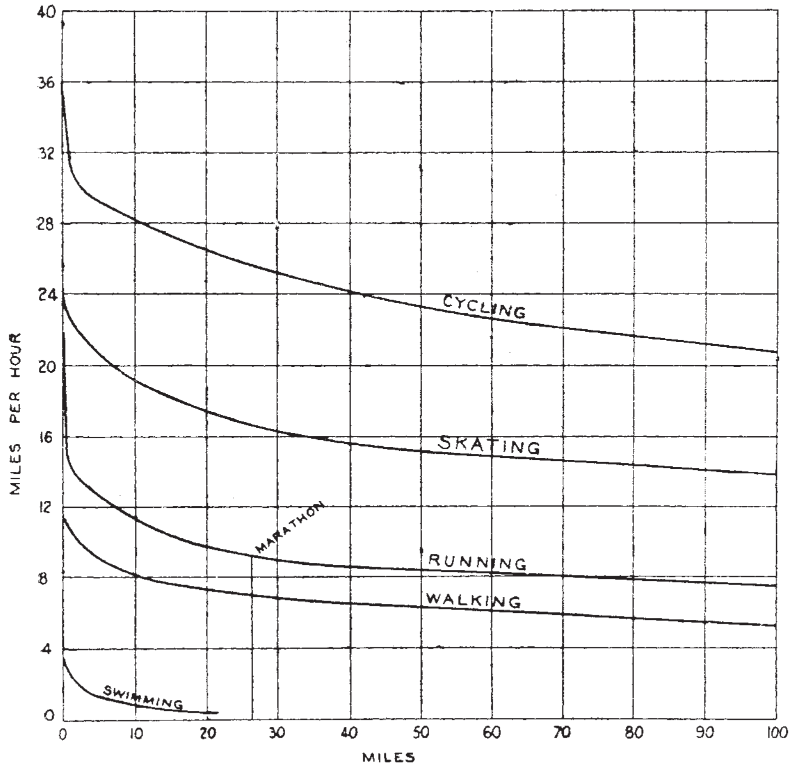

FIG. 2.—Speed Records for Human Muscular Effort.

We do not know the speed of the original historical run from Marathon to Athens, but we do know that Dorando ran the modern Marathon from Windsor Castle to the Stadium at Shepherd's Bush, a distance of 26 miles 385 yards in (to be exact) 2h. 55m. 18 2-5s., or at the rate of 9 miles per hour, which, you see, fits very well on our curve.

We may notice in passing that in walking fast and starting to run the arms swing in time with the opposite leg, as in the modern picture on the diagram exhibited. In the picture, however, copied on the same diagram from an ancient Greek vase, although the attitude of the legs is the same, it might appear at first sight as if the arms were swinging in the contrary way. As a matter of fact, a closer examination shows that in all the figures on the vase the arms are in the same position, although the legs are in different phases. This seems to indicate that the arms of a Greek runner were held in a fixed position as shown, and, from the position of the hands, with the evident intention of cutting the wind. If this is true, it indicates that even then it was clearly recognised that if there was any effect of the wind it was just as important behind as in front, a matter I shall have to allude to hereafter.

What man can do by his muscular effort in the water is shown by the small curve in the corner. The greatest distance shown (Fig. 2) is about 21 miles by Captain Webb at about 1 mile per hour, although for a short distance it will be seen that a man can swim at about 4 miles per hour. I do not put in flying, because man has not yet flown by his own muscular effort, and flying men to-day are using engines of from 20 horse-power to 100 horse-power, *i.e.* from 200 to 1000 *man-power*. Gliding *per se* is no more than falling through the air (more or less) gradually, as in a parachute.

Before proceeding to see what man has done to increase his powers of purely muscular locomotion by means of mechanical devices we will study the details of locomotion in the other animals. We are able to do this by the method of Mr. Muybridge, since developed in the invention of the kinematograph, and which was explained by Mr. Muybridge for the first time in this country about thirty years ago in a lecture in this hall.

Take, first, the galloping horse. The lantern diagram shows clearly the various phases in the action of a horse, and shows how the animal is not only able to attain its high speed by its length of stride, but by doing what man cannot do to the same extent—drawing up its body and in springing forward, using alternately its fore and hind feet, so as to get a stride which no two-footed creature could attain on the level ground. I may point out that the kangaroo, though using only two legs, makes effective use of its tail in the spring. The horse springs clear of the ground off its forefeet, only you will notice that it uses both its fore and hind legs as the spokes of a wheel on which it rolls when walking (exactly as man does), though it rolls and springs alternately in galloping. The same kind of diagram could be constructed for the effort exerted at different speeds by the horse, as has been produced by Marey for the man, only the distribution of energy would probably be very different.

Turning next to other animals, it is interesting to observe that a greyhound gets its high speed in proportion to its size owing to the great flexibility of its long body, which enables it to draw its hind legs forward each time for the next bound, and also bound forward both from its fore and hind legs. The other animals in galloping have each the same general kind of movement, although the deer, curiously enough, only bounds from its hind legs, and differs in this respect from the horse; and also it will be noticed the want of flexibility in the body of an animal may be one of the causes of its relatively slow speed. But whether it be man, horse, dog, or any other animal, the same characteristic is found, namely, that locomotion, apart from the bounding action, takes place by a sort of rolling action on the ground. The idea which had persisted since the delineation of horses in Assyrian and Egyptian pictures, that both the fore or both the hind legs are put on the ground simultaneously, is thus exploded. As Mr. Muybridge truly said: "When during a gallop, the fore and hind legs are severally and consecutively thrust forwards and backwards to their fullest extent, their comparative inaction may create in the mind of the careless observer an impression of indistinct outlines; these successive appearances were probably combined by the earliest sculptors and painters, and with grotesque exaggeration adopted as the solitary position to illustrate great speed." As a matter of fact, each leg in turn, as it rests on the ground, stops for a moment just as much as in the forward position above mentioned, and if you watch a dog galloping you can see quite clearly the rolling stroke action I have mentioned.

With the above facts in mind, we can understand exactly the limitations to animal locomotion. In the words of Mr. Muybridge:—"When the body of an animal is being carried forward with uniform motion, the limbs in their relation to it have alternately a progressive and a retrogressive action, their various portions accelerating in comparative speed and repose as they extend downwards to the feet, which are subjected to successive changes from a condition of absolute rest, to a varying increased velocity in comparison with that of the body." Hence all animal locomotion absolutely lacks that continuity of movement, the production of which we shall see is the distinguishing feature and the direct cause of the high speeds attained in mechanical locomotion.

The exchange of the intermittent movement of nature for one having the desired continuity of movement has been effected by means of what is possibly the greatest and yet the simplest of all human inventions, namely, the wheel. The wheel was made and used probably thousands of years before man learnt to replace muscular effort by that of steam and the other forces of nature, the origin of the wheel being absolutely lost in antiquity.

From the models which I now show will be noticed the way in which the wheel acts and how it overcomes the defect of animal locomotion, giving a rotary and continuous movement instead of a reciprocating and variable one. At one and the same time the wheel, therefore, does away with the three causes of loss shown in the diagram as occurring with animal locomotion. The mere use of the wheel has enabled man himself, by his own muscular effort, enormously to increase his individual power of locomotion. The top curve on Fig. 2 shows, in comparison with the other curves of walking and running, his unpaced records on a bicycle, in using which it will be realised that all three causes of loss which occur in running and walking are obviated. You will notice a similar difference in speed as the distance varies to that which is made evident in the curves for walking and running. For the distance of 100 miles the average speed is thus only 21 miles an hour, while that for $\frac{1}{4}$ mile is more than 35 miles an hour. In view of the results shown by the curve, it is not surprising that the bicycle has entered largely into the conditions of modern life. I am not able to give you any exact figures of the quantity of bicycles turned out each year in this country, but I can tell you that in the Post Office alone there are now 12,000 bicycles employed, and their number is always on the increase; the distance covered on them by men and boys in the year is more than 120,000,000 miles

I have not dealt with *paced* bicycle records, as such are not the result of muscular effort, but of being pushed along by the current of wind which follows up the pacing machine such as occurs when a man on a "push" bicycle is paced by a motor vehicle. In a record first set up in America for 60 miles an hour on a bicycle, a man was paced by a locomotive engine, running at 60 miles an hour along a special track; the rider was nearly killed when he tried to drop behind, owing to the whirlwind which was being dragged along by the engine; ultimately his life was saved by his being lifted bodily off his bicycle on to the locomotive. There is no record as to what became of the bicycle.

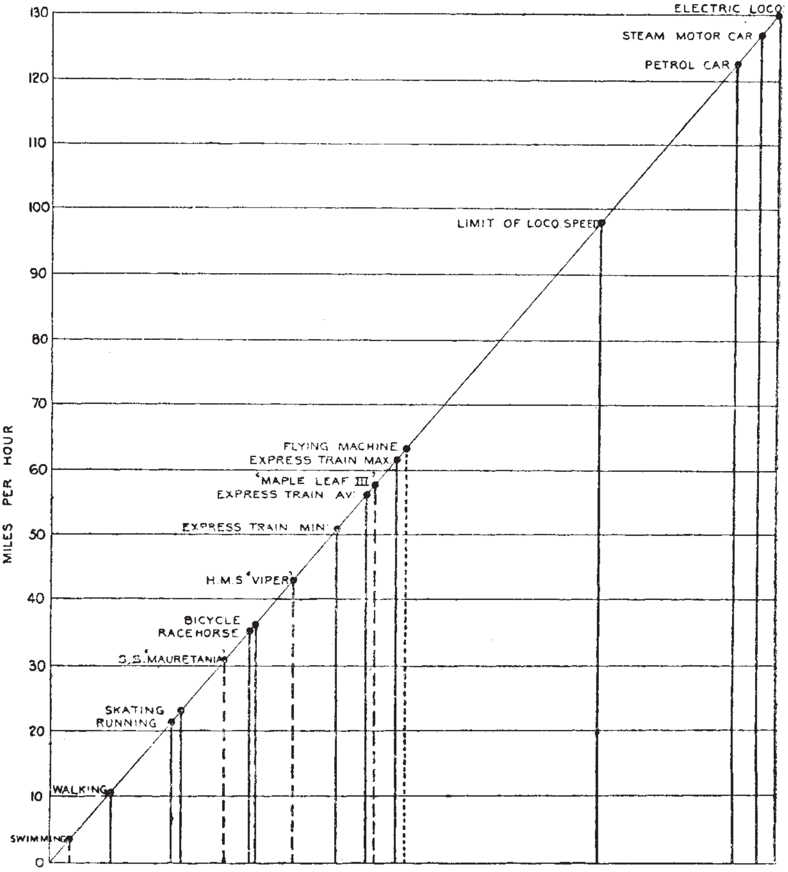

Fig. 3.—Graphical Table of Maximum Speeds.

Curiously enough, records for ice skating and roller skating are almost the same, and far below that on the bicycle, which I think proves distinctly that the reciprocating movement of the limbs limits man's powers, whether he is sliding on the ice or using wheels as with roller skates. This is so, notwithstanding that he carries along with him when on a bicycle the extra weight of the bicycle, but the reciprocating movement of his legs is so slow, owing to the gearing up of the driving wheel, as to give him the material advantage shown by the respective curves. Further, in skating, there is no doubt that the movement of his limbs entails a certain amount of rising and falling, as well as reciprocating motion and consequent loss which occurs in running.

Now, in theory, the wheel is perfect, and in the case of a perfectly hard, circular wheel, rolling on a perfectly hard track, there should be no resistance. This you can well imagine from the lantern model which I now show in operation. In this there is no appreciable resistance, but it is just in this direction that the wheel has defects unknown to nature's methods, since men and animals move upon the ankle joint in a quite superior way to the rolling of an ordinary wheel. In passing I may remark that the more man improves the roads, and the higher his standard of locomotion becomes, the more will he feel the need of a mechanical walking machine (it will be a *walking* machine, though possibly moving at 20 miles per hour) to progress over parts of the earth where roads do not exist, or are still in an evil condition. The better his mechanical appliances for producing such a walking machine, the sooner will this come about, as this is really a vital factor in the solution of the problem. No wheel, however, is quite hard and round, and no road is quite hard and smooth, and there is always an arc of contact, more or less appreciable, which causes a loss, since rubbing takes place instead of true rolling, as shown in the next lantern slide. The next lantern working model I show illustrates the other effect, in which the wheel meets obstacles and is deflected by them from its course, giving exactly the same kind of loss which I showed you takes place with a man in walking, and which is made apparent by making the car write its own record on a piece of smoked glass, exactly as my assistant wrote his record of rise and fall on the blackboard.

Thus there are two ways in which the wheel can be improved :—

(1) Is by perfecting the wheel and hardening the track—and that is the secret of the development of the railway system.

(2) The other is by causing the obstacle to be absorbed in the tyre of the wheel—that is the real secret of the success of the pneumatic tyre.

The working model now on the screen illustrates the latter point, and shows at once how the three causes of resistance to animal locomotion are overcome.

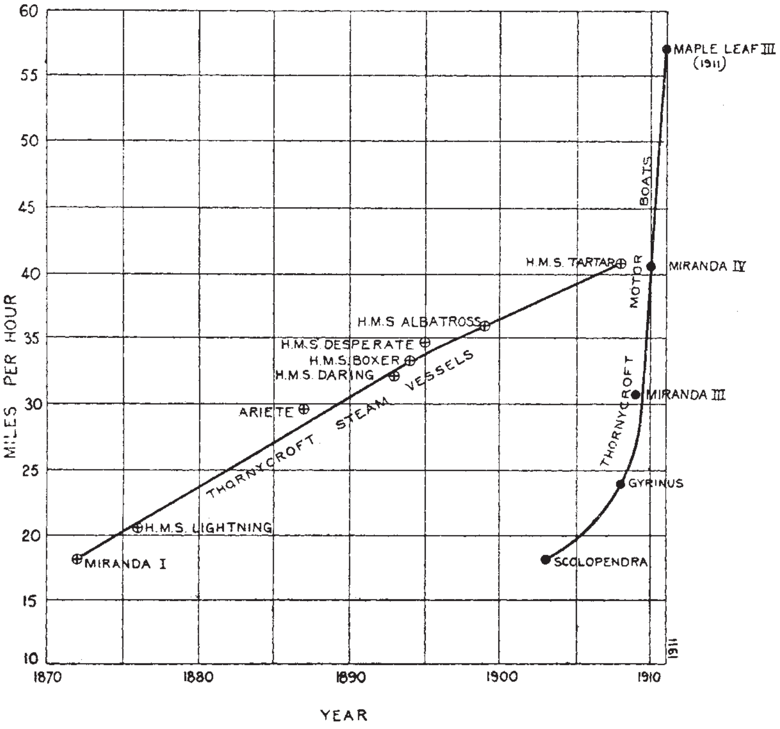

FIG. 4.—Speed Records for Thornycroft Warships and Motor Boats.

To-day we can replace the muscular energy of man by almost unlimited mechanical power, and Fig. 3 is a comparative speed chart which I have prepared and which indicates the enormous advance in the speed record which has been made over the best unaided muscular efforts of any animal. It is curious to see that the highest speed ever attained on a railway is closely approached by that obtained with motor vehicles. The records for the latter are as follows :—

A Darracq car of 200 horse-power has done 122½ miles an hour for 2 miles. A Fiat car, driven by Nazarro at Brooklands, 126 miles an hour. A Stanley steam car, 127 miles an hour, and a Benz car has done 127½ miles an hour.

The maximum recorded speeds of a railway were on the experimental line of Messrs. Siemens, on the Berlin-Zossen High Speed Railway, where a speed of rather more than 130 miles an hour was attained. The electric current employed was 10,000 volts, 400 horse-power motors being used. On the Marienfel-Zossen experimental line, the speed attained with 250 horse-power was apparently rather less, though in that locomotive four motors were employed, the current being, as in the other case, 10,000 volts. The lantern diagrams are a picture of the vehicles actually employed, and of the track on which the experiments were made. As a set-off against the sober engineering pictures, I show a picture taken from an American motor journal, illustrating a motor vehicle and locomotive at top speed, the former passing on a level crossing in front of the latter.

The foregoing are the record speeds so far obtained of mechanical locomotion, and it will be interesting to see what are the record speeds attained in the other elements. Until the other day, as Mr. Parsons told us in his lecture, the speed on water which has never been exceeded was that of the ill-fated turbine boats, *Viper* and *Cobra*, of about 43 miles an hour. The ship which at present holds the record for speed is the torpedo destroyer *Tartar*, built by Messrs. John Thornycroft, this, under Admiralty tests, giving a speed of 41 miles an hour.

The diagram, Fig. 4, shows in an interesting manner what the progress in speed has been for this class of boats during the last few years, and may be taken as typical, and about which curves Sir John Thornycroft writes as follows :—

"I do not think the curve would be materially altered if vessels of other builders were brought in, although there would naturally be more points on it."

I am able, however, to give you the results to-night of something which has altogether put in the shade even the speeds of the two first-mentioned boats. This has been attained by a boat which, though corresponding in some respects with previous hydroplane boats, has been designed by Sir John Thornycroft to possess a certain amount of seaworthiness. The rate of progress in the increasing speeds in this class of boat is shown on a separate curve, Fig. 4, from which you will see that the celebrated *Miranda* held as a hydroplane the record with the *Tartar* for speed, the *Ursula* also holding the record of about the same speed as a motor-boat. Only a few days ago, however, the new boat *Maple Leaf III.* has attained the extraordinary speed of nearly 50 knots, that is to say, a speed approaching 60 miles an hour, using 600 horse-power to effect this speed. To use a vulgar expression, this certainly smashes all previous records for speed. I do not pretend to give exact figures in this case, because such have not been officially taken, but the statement is probably on the low side as the boat has not been yet properly tuned up. You will see one remarkable thing from the curve, namely, that the rate of progress has been so rapid in this class of boat, and the curve rises so steeply, that in about three months' time there is due from Sir John Thornycroft a boat which will travel at about 100 miles an hour. I am afraid, however, it would not be fair to press this graphical argument quite so far.

Through the kindness of Sir John Thornycroft, and Mr. Edgar, the owner of the *Maple Leaf*, I am able to show both the *Miranda* and the *Maple Leaf III.* The latter, you will see, is travelling at such an extraordinary rate that the water which is lifted up does not fall to the surface again until the boat itself has travelled several lengths away. You may be interested to see a model of this last boat, which has been kindly prepared for me to show to-night, as well as the *Tartar* and *Miranda.* You will notice the form of the *Maple Leaf III.* is that of a steeped hydroplane, which in a modified form was first suggested by Mr. Ramus many years ago; it is the secret of placing the weight, and also the development of light engines giving large horse-power, which has enabled the dream of Mr. Ramus to be fulfilled.

Turning to the last of the three elements, namely, air, it was my intention to have dealt with it at greater length than I now find it is possible to do, but, thanks to the daily Press and illustrated journals, this subject is as fresh in the minds of everybody as it is familiar. It is not necessary in this room to remark that the wild talk of almost incredible speeds has very little foundation. Bodies move quickly enough in the air, and very often far too quickly, but what is generally overlooked is that the difficulty of the problem lies in the matter of supporting the body in the air rather than moving through it, a problem which is very much simpler for land and water. The human body itself, while of about equal specific gravity with water, is about 800 times as heavy as air, and probably, taken in conjunction with the motor and aëroplane, the weight which has to be supported is several thousand times as heavy relatively to the air which it displaces. Inasmuch as the support of the air necessitates the use of an inclined plane and a corresponding expenditure of energy, the speeds made horizontally and independently of the wind have, at the present time, barely exceeded half the record speeds made on wheel vehicles. As a matter of fact, only the other day the record for passenger flight was broken by M. Nieuport at Mourmelon, when he flew with two passengers for 1h. 4m. 58 1-5s., and covered 68·35 miles at an average speed of 63 miles per hour. It is difficult to say exactly what the true record speed at present is round a course, but we may safely take it as probably under 70 miles an hour, the record being, so far as I have been able to ascertain, by M. Nieuport on March 9 this year at Chalons—68 miles 168 yards in the hour.

We now see the relative position of the record speeds in the three elements on our speed chart, Fig. 3, and it is obvious that while on land the speed has been far exceeded of the fastest animal, on water it has probably only recently surpassed that speed, while in the air, in all probability, it is still considerably below it. We must not, however, from this argue that flying speeds will for safe flying machines rise so far beyond that of birds as land locomotion has risen above the speed of animals, for it looks as if the speed records on land would be at least equal for some time, if not greater, than that possible with safety in the air. At the same time, there is no doubt that speed is the one great factor of safety in flying, and aërial speed records are sure to go on rising year by year, but time does not permit me to pursue this subject further to-night.

Instead of vague surmises as to what may be done in the future, let us spend a few minutes looking into the question of these limits.

The two chief things on which the limit of speed in locomotion will depend are:—

(1) The motive power available.

(2) The resistance, and the manner in which those resistances operate.

But inasmuch as we are not merely considering the human body as a projectile, we do not take into account such speeds as have been attained by man in such ways as, for instance, in a high dive, say, of nearly 100 miles an hour, or even the thrilling descents such as are made in a bobsleigh. We must really consider speeds which can be made with safety; and there are two further questions which arise:—

(1) Knowledge as to possible obstacles, coupled with a power of safely stopping within the distance to which our knowledge extends, *i.e.* signalling and brakes.

(2) Vibration.

These two latter really limit conditions of high speed for practical travelling.

In daily life, the limiting conditions of speed in travelling depend largely on the distance in which we can safely come to rest. As the population increases and there is less room for everybody, the question of brake-power becomes more and more important, and with it, of course, the power of starting from rest quickly, or, to put it in scientific words, the power of rapidly effecting both positive and negative acceleration. We are very differently constructed from the particles of air in which we live, and do not yet travel as fast, but fortunately, as yet, we are not quite so crowded, since, according to Lord Kelvin, they move about amongst each other at the ordinary atmospheric temperature and pressure at an average speed of 1800 miles an hour, and they cannot avoid fewer than five thousand million collisions in every second. As you see in the streets, and as I shall show you with regard to suburban traffic, high speed is becoming more and more a question of starting and stopping rapidly. I remember in the early days of cycle racing, in order to lighten the machine, the racing men had no brake, until they found what is now well recognised—that the speed at which you can travel depends upon the safe distance in which you can stop. I can illustrate this by dropping an egg from the dome of this building, which I can do without causing it any injury, even when it is travelling at 30 miles an hour, if I have proper means for bringing it to rest. I also drop a wineglass from the same height, and bring it to rest quite safely.

Owing largely to the perfection of the continuous brake, the speed records obtained on several railways are from 96 to 98 miles an hour, which I have put down on the diagram, and it is possible that 100 miles an hour has been reached, and even exceeded; but this is a very different matter from the highest express running which is found really practicable. You will see on the speed chart, Fig. 3, a line indicating the average railway speeds of the fastest running (without stopping) for the fifteen principal railways of the country. The average distance of the quick runs is 51·7 miles, and the average fastest running is 56·2 miles per hour. On either side of this line are the two fastest speeds, namely, 61½ miles per hour for 44¼ miles on the North-Eastern Railway from Darlington to York, and the lowest of these is 51 miles an hour, over the 51 miles from Victoria to Brighton on the London, Brighton and South Coast Railway. This shows how little the high speeds of all the railways of this country differ from one another, and indicates, at any rate for the present conditions, the highest speeds of travelling found suitable to our wants.

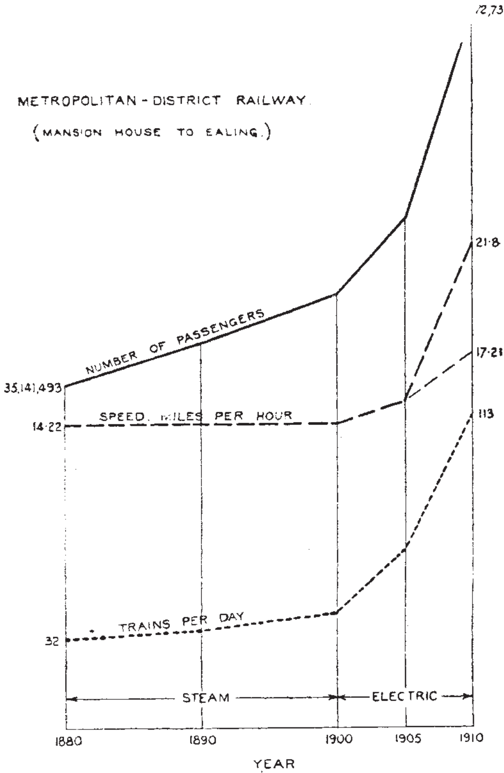

Fig. 5.

I will take as another illustration of actual travelling the case of suburban traffic; and we have only time for one example, namely, the traffic from the Mansion House to Ealing on the Metropolitan and District Railway, the details of which have been kindly provided by Mr. Blake, the superintendent of the line. Fig. 5 shows in graphical form the quickening in speed from the opening of the line in 1880 to the present time. You will notice that this increase of speed has been followed by remarkable results; the first immediate result is the possibility of a greater number of trains, and the curve of the rise in the number of trains is shown on the diagram; but the really significant feature is the rise in the number of passengers carried, 35,000,000—72,000,000, which is the direct result of the increased facility in travelling. Now it is in such a case that the importance of the signalling and braking come to be almost pre-eminent, quite apart from the mere mechanical problem.

I may point out that the District Railway, in common with most other electric railways of this country, has what is known as a "track system of signalling," which, apart from the fact that the driver holds what is known as "the dead man's handle," which upon being released causes the train to stop, the train independently stops itself upon coming to a portion of the line not cleared by the previous train.

I have given you some examples that this country is not so far behind as we are so often told; and we have another in the fact that the District Railway has created a most beautiful system, by which the signalman is now absolutely independent of fog or darkness; he can see every train, or rather its picture, as it moves along the track in an illuminated diagram in front of him. No one could watch, as I have had the privilege of doing, the operation of this system in a signal-box without feeling certain that it must become universal in a very short time. You may like to see an actual panel from a signal-box and a view of what the interior is like with the signalman operating, instead of cumbrous levers, only a few small handles.

With regard to the question of vibration and oscillation, these are gradually being diminished as machinery is perfected, and you will see from the model illustration that they are important, and may become very serious. They have, for instance, given Mr. Brennan much trouble in perfecting his wonderful mono-rail, with which we shall yet perhaps see every record broken; and you will remember Mr. Parsons' statement in this hall a week or two ago that an ounce out of balance on the Laval turbine represents an actual pull at the axle of no less than a ton.

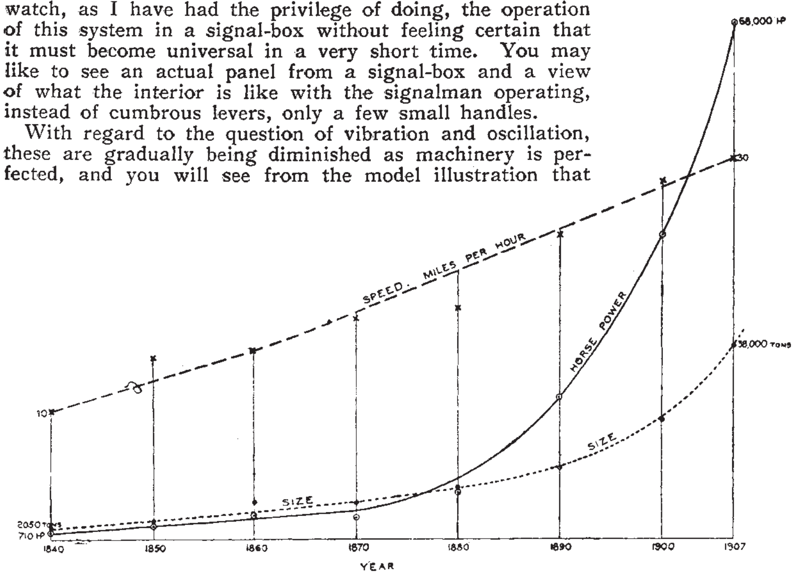

FIG. 6.—Progress in Atlantic Steamers (Cunard).

There are many other features which I have not time to enter into. There is one, however, which I will briefly touch upon, as it is the secret of our safe railway travelling. I will illustrate the matter by an experiment in which a pair of wheels connected by an axle keyed firmly to both are made to run along a pair of rails. You will notice that the wheels are "coned" instead of having cylindrical rims, and it is easy to see that any movement sideways is at once corrected automatically, and within certain limits no rim at all is required for the flanges in order to keep the wheels upon the rails. The same model illustrates the important property of "super-elevation" applied to the outer rail of a curve. You will see, with proper super-elevation, the wheels run safely round this sharp curve even at a high speed. Time does not permit me to enter at any length on the question of development of power or the nature of resistance to motion. I will content myself with saying that, with regard to the former, we have already seen that the power of flight has been made possible by the invention of the small high-power internal-combustion engine, and it is to the same invention that the marvellous speeds obtained with small boats is due. We can scarcely realise what will be the result when the internal-combustion engine has been developed further for the purpose of locomotion. Our prospects of a further great advance in speed record-breaking appears to lie in this direction, and we already hear of a new car of 250 horse-power with which a speed of 140 miles per hour is confidently expected.

On water, as on land, our actual speed of travelling falls far below maximum speed records, and we do not commercially travel at much more than half the possible speed, as you see from Fig. 3, where the speed of the *Mauretania* is shown graphically. Fig. 6 is a chart of the progress of Atlantic shipping, taking the Cunard line as an example, and these curves indicate that the rate of increase of horse-power and tonnage is rising far faster than the rate of speed, and indicates how relatively highly the rate of power has increased for the gain of speed.

We have now passed briefly in review the nature of the problems which confront us in our continuous efforts to increase the safe and practical speeds of mechanical locomotion. We see that at the root of it all lies the question of artificial power and the harnessing in compact and convenient form the stored-up sources of energy in nature in order to overcome the opposing resistance, and we can realise that, although we have obviously reached the limits of animal locomotion, we are far from having reached any limitation in regard to the speed of self-propelled machines. We see that in all three forms of locomotion, earth, air, and water, the advance has been far more rapid during the last few years than ever before, and we can realise that there is yet a considerable margin by which speed of travelling could be increased as the demand for it is made; and nothing is more certain than that the demand will be made.

I began my lecture by pointing out why speed was instinctively taken as a test and a measure of locomotion from the earliest times. Shakespeare makes one of his characters say, "The spirit of the time shall teach me speed," but he might have said this of any period equally with that of King John, though never more so than of to-day, for the changes in the requirements of civilisation have only altered in detail, and speed is of as much importance as ever in the struggle of life. The probably unconscious recognition of this fact has always led question of speed to be raised as prime factors in proposals for new modes of locomotion, and it is interesting to look back only a comparatively few years to see, in raising these views, this was always the case, but how little any ideas of future possibilities were realised. When George Stevenson, backed up by a few courageous and enterprising men, was fighting the battle of the railway, and in particular trying to secure the passing of the Bill for improved communication between Liverpool and Manchester, the question of speed was the most important one raised; the opposing counsel, Mr. Harrison, spoke as follows:—"When we set out with the original prospectus, we were to gallop, I know not at what rate; I believe it was at the rate of 12 miles an hour. My learned friend, Mr. Adam, contemplated—possibly alluding to Ireland—that some of the Irish members would arrive in the waggons to a division. My learned friend says that they would go at the rate of 12 miles an hour (with the aid of the devil in the form of a locomotive, sitting as postilion on the fore horse, and an honourable member sitting behind him to stir up the fire, and keep it at full speed. But the speed at which these locomotive engines are to go has slackened: Mr. Adam does not go faster now than 5 miles an hour. The learned serjeant (Spankie) says he should like to have 7, but he would be content to go 6. I will show he cannot go 6; and probably, for any practical purposes, I may be able to show that I can keep up with him *by the canal*. . . . Locomotive engines are liable to be operated upon by the weather. The wind will affect them; and any gale of wind which would affect the traffic on the Mersey would render it *impossible* to set off a locomotive engine either by poking the fire or keeping up the pressure of steam till the boiler was ready to burst." The committee, after hearing the arguments of Mr. Harrison, threw out the Bill for the Liverpool and Manchester Railway by a majority of 19 to 13. In order to realise that the above ideas were general, the following may be quoted from the great journal of the day, *The Quarterly*:—"What can be more palpably absurd and ridiculous than the prospect held out of locomotives travelling *twice as fast as stage coaches?* . . . . We trust that Parliament will, in all railways it may sanction, limit the speed to *eight or nine miles an hour*, which we entirely agree with Mr. Sylvester is as great as can be ventured on with safety."

Even in more recent times we see the struggle for the road locomotion question turned on one of speed, and the supporters of the new departure were unable to make any headway for many years, partly because the speed limit was put at between 3 and 4 miles an hour, that is, the limit of a walking man. A few years ago the speed of 12 miles an hour which, after a great struggle, was obtained, gave place to 20 miles an hour. You can see from the diagrams which Mr. Legros gave in a recent paper before the Institution of Mechanical Engineers, and which have been brought up to date, how the speedier self-propelled vehicle is leading to the disappearance of the horse, at any rate in London, and the difficulty which most people seem to feel is not how to get above the speed limit, but how to keep within it, and the papers show, by a daily crop of sad examples, how only too painfully easy it is not to do so.

Nothing points more clearly to what I have indicated as the basis of our instinctive desire for speed, as the fact that our measure of speed is entirely relative. Thus 60 miles an hour would be a slow speed for a motor-car on a racing track, as seen by the speeds of the motor races at Brooklands last Saturday (April 25th), but this speed, which would be even quite good along the open road to Brighton, would be considered decidedly on the high side for motoring along the Strand. Our ideas of what is slow and what is fast are largely derived from habit, and particularly from surrounding conditions and from our mode of estimation. For instance, we have been carried in this hall during the last hour with the surface of the earth round its axis a distance of about 600 miles. This speed would require a line on our speed chart about as high as the dome of the hall to represent it graphically. But if we judge the speed from observing the apparent rate of motion of the moon and stars overhead, we could never realise this. Far less could we realise by the change in the seasons the speed at which we are travelling with the earth round the sun, accomplishing a distance, as we do, of 540 million miles in 365 days, which represents, roughly, a distance of 60,000 miles per hour. We have thus travelled together, since we came into this hall, a speed of 60,000 miles. The line required on our chart for this speed would be about as high as St. Paul's Cathedral. But these speeds fall far short of those of certain heavenly bodies with which we are familiar, such as the meteors, some of which are travelling at 160,000 miles an hour, and the recent comet, which probably exceeded this speed one part of its journey round the sun; whereas the fastest speed which man has, up to the present, been able to produce, even in a projectile, amounts to between 2000 and 3000 miles an hour (the Krupp 10·7 centimetre having a velocity of 3291 metres per second, and a 6-inch Vickers, 3100 metres per second). The highest projectile speeds we have attained are thus only about one-tenth of the speed at which Jules Verne fired M. Barbicane and his friends off, in order to overcome the earth's gravity and reach the moon, since the speed he required was 12,000 yards per second, or 24,000 miles per hour. Such an idea we are quite justified in thinking absurd, but we might have been justified in thinking many of the things absurd which Jules Verne wrote about, only forty years ago, and which have since come to pass. Take "Round the World in Eighty Days." In that case it cost Phineas Fogg 19,000*l.* to take himself and his servant round the world in eighty days. A telephone inquiry of Messrs. Cook an hour or two ago elicited the fact that anyone present can start to-morrow morning and go round the world, with a servant, in less than half the above time, and for less than one-fiftieth of the above sum.

Thus though, impelled by instinct, man will ever continue to strive to increase his speeds of travelling, and with the refinement of machinery and invention doubtless succeed in doing so, it may be safely said that, notwithstanding the still increasing upward angle on some of the speed lines of the charts I have shown to-night, this rate of increase will before long begin to take place at a continually diminishing rate. Such feats as the journey from Paris to London within the hour may be regarded as quite a feasible engineering proposition in the future, though possibly a tube will be used for the purpose, without the employment of wheels, and with a modification of the pneumatic system of that great genius Brunell. We should, however, in doing this journey, be only travelling at half the rate we are actually moving at this spot round the earth's axis, while to do it at the rate we are travelling round the sun, we should only occupy a quarter of a minute. This latter speed, apart from the fact that it is getting very near the point at which meteors fuse with the friction of the earth's atmosphere, seems to be quite outside the limit of the possibilities of artificial locomotion by man, but who can tell how far we shall go towards it!

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—It is proposed to confer the degree of Doctor of Science, *honoris causa*, upon Dr. T. W. Richards, professor of chemistry in the University of Harvard.

On Thursday, May 11, a Grace will be offered to the Senate proposing that the Most Reverend St. C. G. A. Donaldson, D.D., of Trinity College, Lord Archbishop of Brisbane, be appointed as the representative of the University at the inaugural ceremony of the Queensland University to be held at Brisbane on June 1.

The special board for biology and geology has nominated Mr. E. S. Goodrich, fellow of Merton College, Oxford, to use the University table at Naples for one month.

Mr. A. R. Hinks will deliver a lecture on Monday, May 8, at 2.30 p.m., on "Recent Progress in the Measurement of the Earth."

On Friday, April 28, a meeting was held in Trinity College to consider the formation of a Cambridge University Eugenics Society to promote the study of heredity in its bearings on racial and social questions. The Dean of St. Paul's presided. It was resolved to form such a society, and the following officers were elected:—*President*, Prof. Seward, F.R.S.; *council*, the Rev. the President of Queens', Mr. Horace Darwin, Prof. Punnett, Mr. L. Doncaster, Mr. W. C. D. Whetham, Mr. J. M. Keynes, Mr. R. A. Fisher, Mr. C. S. Stock, Mr. R. W. Pyne, Mr. G. K. M. MacMullan, and Mr. E. P. Stapleton

OXFORD.—The Halley Lecture for 1911 will be delivered in the examination schools on Monday, May 22, at 8.30 p.m., by Prof. H. H. Turner, F.R.S., the Savilian professor of astronomy. Subject:—"The Movements of the Stars."

A COURSE of eight lectures will be delivered by Dr. W. M. Bayliss, F.R.S., on "The Mechanism of Oxidation in Plants and Animals," at University College, on Fridays at 4.30 p.m., beginning on May 5. These lectures are open free to all internal students of the University of London and to such other persons as are specially admitted.

DR. H. N. ALCOCK has been appointed to the chair of physiology in McGill University, Montreal, Canada. Dr. Alcock holds at present the post of lecturer on physiology